

WATER QUALITY ENGINEERING SPECIAL STUDY NO. 24-0044-78
EVALUATION OF ENVIRONMENTAL DEGRADATION FROM PRIOR DDT WASTE DISPOSAL
REDSTONE ARSENAL, ALABAMA
20-25 JUNE 1977

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US ARMY
ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MD 21010



DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

Mr. Kibler/cf/584-3843

HSE-EW-S/WP

6 JAN 1978

SUBJECT: Water Quality Engineering Special Study No. 24-0044-78, Evaluation of Environmental Degradation from Prior DDT Waste Disposal at Redstone Arsenal, Alabama, 20-25 June 1977

Commander
USA Materiel Development and
Readiness Command
ATTN: DRC SG
5001 Eisenhower Avenue
Alexandria, VA 22333

A summary of the pertinent findings and recommendations of the inclosed report follows:

This study was conducted to assess the extent of potential health and environmental threat of DDT migration from a DDT waste disposal site at RSA, Alabama. Analytical results indicate that ground water used as a drinking water supply in the RSA area is not currently contaminated with DDT. However, sufficient concentrations of DDT exist in sediment within the drainage system downstream of the disposal site to contaminate the Tennessee River during heavy storm periods, and fish downstream of the disposal site may be unfit for human consumption. The threat of further environmental degradation is sufficient to justify immediate corrective measures to control erosion of DDT-contaminated material from the disposal site.

FOR THE COMMANDER:

1 Incl
as (15 cy)

John P. Piercy
JOHN P. PIERCY, P.E.
COL, MSC
Director, Environmental Quality

CF:
HQDA (DASG-HCH)
Cdr, HSC (HSPA-H)

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1. AUTHORITY.

a. AR 200-1, Environmental Protection and Enhancement, 7 December 1973, with two changes.

b. Message, 151739Z Feb 77, from Cdr, DARCOM to Cdr, HSC, with information copy to Cdr, USAEHA, subject: Waste Effluent Discharge Survey-Redstone Arsenal, Alabama.

2. REFERENCES. See Appendix A for listing of references.

3. PURPOSE. To assess the potential health and environmental threat of DDT migration from a prior DDT waste disposal site at Redstone Arsenal, AL, and to provide recommendations for corrective action.

4. GENERAL.

a. Abbreviations. Abbreviations and units utilized in this report are included in Appendix B.

b. Background.

(1) During a preliminary survey for a water quality engineering special study to identify point source discharges at RSA (Special Study No. 24-0034-78), RSA personnel indicated possible environmental degradation resulting from DDT migration from the abandoned Olin Chemical Site. Preliminary samples from the area were analyzed, yielding the following information on DDT content:

	<u>Sediment</u>	<u>Water</u>
Sample I	1385 ppm DDTR*	66 ppb DDTR*
Sample II	854 ppm DDTR*	16 ppb DDTR*
Sample III	70 ppm DDTR*	23 ppb DDTR*

* DDTR = DDT and its isomers

Use of trademarked names does not imply endorsement by the US Army, but is used only to assist in identification of a specific product.

These samples were taken from the stream draining the area. They indicated alarmingly high DDT levels as compared with other monitoring data collected by this Agency (see the Table, Appendix D) and evidence of DDT migration from the site to surface waters.

(2) A separate water quality study was initiated to assess the extent and impact of the pesticide migration. The field portion of this study was conducted during the period 20-25 June 1977.

c. History.

(1) DDT manufacture at RSA was started shortly after World War II by Calabama Chemical Company utilizing a leased Lewisite Gas Manufacturing Plant. Later, Olin Chemical Company purchased Calabama Chemical Company and continued to manufacture DDT at RSA.

(2) In October of 1969 the Federal Water Pollution Control Administration recommended a discharge limit of 20 ppt of DDT in the wastewater discharge from the manufacturing facility. Because of the attempt by US Army Missile Command to enforce this standard and the pressure and eventual suit by conservation groups, the Olin Chemical Company announced in June 1970 that it would discontinue manufacture of DDT at RSA and give up its lease.

(3) Shortly after the announcement, the Olin plant manager, trading as Calabama Chemical Company (without apparent leasing authority), began manufacture of TCAN and methoxychlor. In February 1971, the Assistant Secretary of the Army for Installations and Logistics announced the termination of the Olin lease as of 1 April 1971 and allotted Olin Chemical Company 120 days to cease operations at RSA. At the end of the 120 days, all manufacturing had ceased.

(4) Remaining DDT residue was disposed of at the plant site by mixing with lime and ferrous sulfate and then covering with clay. Hence, the plant site also became a DDT disposal site. The drainage ditch from the disposal site was left open in anticipation of DDT degradation by ultraviolet rays of sunlight.

5. FINDINGS AND DISCUSSION.

a. General. The survey, as conducted, is divided into four areas of investigation:

- (1) Potable Water Supply Contamination
- (2) Threat to Fish and Wildlife
- (3) Water and Sediment Migration from Site

(4) Disposal Site Evaluation

In addition to the discussion in the main body of this report, there is detailed discussion of the following subjects in Appendices C through F:

Appendix C - Analytical Procedures

Appendix D - Regulatory Status of DDT and Current Environmental Monitoring Data

Appendix E - Ecological Assessment of DDT Discharge

Appendix F - Health Effects Evaluation

b. Potable Water Supply Contamination.

(1) Initial water samples collected from three wells and one spring on RSA yielded levels of DDT contamination ranging from less than 10 ppt to 42 ppt in the well samples and 360 ppt in the spring sample. The detection of DDT in these samples was unexpected due to the impervious clay strata underlying the manufacturing site; therefore, the integrity of these samples was questioned. All four points were resampled, and samples were also collected from the drinking water system. Extreme care was taken to protect the integrity of the samples during collection and transportation. Analyses of these samples revealed no DDT contamination. The detection limit in the analyses was 10 ppt.

(2) USEPA, in its proposed Interim Primary Drinking Water Standards published 14 March 1975 (reference 1, Appendix A), indicated that a possible maximum allowable concentration of DDT in drinking water would be 50 ppb; however, USEPA refrained from issuing any limit until additional studies of DDT in drinking water were performed. In November 1975, USEPA stated, "DDT can be toxic to man at a dose of 851 mg/kg body weight with fatality in a 70 kg man resulting from 30 grams. Ingestion of 1 gram causes tremors and convulsions. Drinking water should not contain more than 0.042 ppm" (reference 2, Appendix A). This reference is pertinent not only in that it suggests a hazardous level in drinking water, but it also gives information relating to ingestion of DDT from other sources, such as contaminated fish and fowl. No RSA potable water samples analyzed to date have approached the hazardous level stated in this reference.

(3) Public Law 93-532, The Safe Drinking Water Act of 1974, authorized the USEPA to establish Federal standards to protect drinking water sources from all harmful contaminants. This legislation provided that interim primary regulations be prescribed initially and that, after a study by NAS, health goals be established and revised primary regulations be promulgated. The NAS report (reference 3, Appendix A) establishes a risk factor of $1.2 \times$

10⁻⁵ based on the consumption of 1 liter of water per day containing 1 microgram per liter of DDT. As interpreted by this Agency and based on the average daily consumption of 2 liters of water per day, the factor would mean a risk of 2.4 persons in every 100,000 population developing cancer from ingestion of 1 $\mu\text{g}/\ell$ (1 ppb) of DDT in drinking water.

(4) The NAS report also states, "Mankind is already exposed to many carcinogens whose presence in the environment cannot easily be controlled. In view of the nature of cancer, the long latent period of its development, and the irreversibility of chemical carcinogenesis, it would be highly improper to expose the general population to an increased risk if the benefits were small or questionable, or were restricted to limited segments of the population." This statement stands on its own merit and, when applied to the RSA contamination problem, it should be noted that no benefit is derived from the exposure to DDT.

c. Threat to Fish and Wildlife.

(1) Observations of Huntsville Spring Branch indicate severe ecological stress due to a wide variety of pollutants. In order to isolate the stress due solely to DDT, and because of the high bioaccumulation potential of DDT and its byproducts in living tissue, a variety of aquatic and terrestrial fauna was collected. Analyses indicate a high concentration of DDT in both fish and bird tissue (see Tables 1 through 3, Appendix E).

(2) Reference 4, Appendix A, documents the detrimental effect of DDT on fish and birds. This reference also explains that use of DDT decimated populations of bald eagles, peregrine falcons and ospreys, thus causing these birds to be listed as endangered species.

(3) The Wheeler Wildlife Refuge is a habitat for the above referenced birds and for migratory waterfowl.

(4) Appendix E of this report sets forth the levels of DDT detected in biological samples collected from the disposal site, Huntsville Spring Branch, and the Tennessee River. Appendix E also discusses the detrimental effect of DDT contamination on the ecosystem.

(5) The FDA has established 5 ppm DDTR in the edible portions of fish as a maximum allowable level of contamination. The levels of DDT detected in this Agency's analyses, as set forth in Appendix E of this report, exceed the FDA limit.

(6) Appendix F of this report sets forth the health risk involved in the consumption of DDT-contaminated fish.

d. Water and Sediment Migration from Site.

(1) In the conduct of this portion of the survey, the following facts must be recognized in any and all data evaluations:

(a) DDT in water is transient. Its presence in measurable concentrations is usually as a suspended solid, a particle attached to suspended solids, a colloidal solution, or a particle absorbed/adsorbed by biological forms. Solubility of DDT is usually considered as 1.2 ppb at a temperature of 25°C.

(b) DDT in sediment is evidence of past and/or continuing contamination.

(c) DDT mobilized by biological fauna can migrate within the aquatic environment without regard to sedimentation patterns. This can account for concentrations of DDT outside of the path of sedimentation.

(d) DDT will degrade in an aquatic environment due to microbiological action. It will also degrade due to ultraviolet radiation, but at a much slower rate due to the limited penetration of ultraviolet light in water.

(2) Sediment samples were collected over the whole distance from the point where the DDT site drainage system leaves the disposal site to the point where Indian Creek joins the Tennessee River. The drainage system is composed (in sequential order) of a man-made drainage ditch, a portion of Huntsville Spring Branch to its confluence with Wheeler Reservoir, Wheeler Reservoir, and a portion of Indian Creek to its confluence with the Tennessee River. This system is shown in Figure 1.

(3) DDTR concentrations in the sediments varied significantly through the drainage system (see Table 1, Appendix G, for analytical data and sample site description). As shown in Table 1, Appendix G, the highest concentration was 5440 ppm and the lowest concentration was 2 ppm. The sluggish stream flow and the changing stream velocity within the drainage system directly affect the rate of sedimentation within various parts of the system. This accounts for orders-of-magnitude fluctuation of DDT concentration. The DDT concentrations in the sediment also decrease proportionately to the inflow of other water sources to the system.

(4) So as to document any addition of DDT to the drainage system from areas other than RSA, sediment and water samples were collected from Indian Creek, McDonald Creek, and Huntsville Spring Branch near the points where each enters the Post boundaries. Analyses of these samples are provided as Table 2, Appendix G, of this report. No significant levels of DDT contamination of inflow waters were detected.

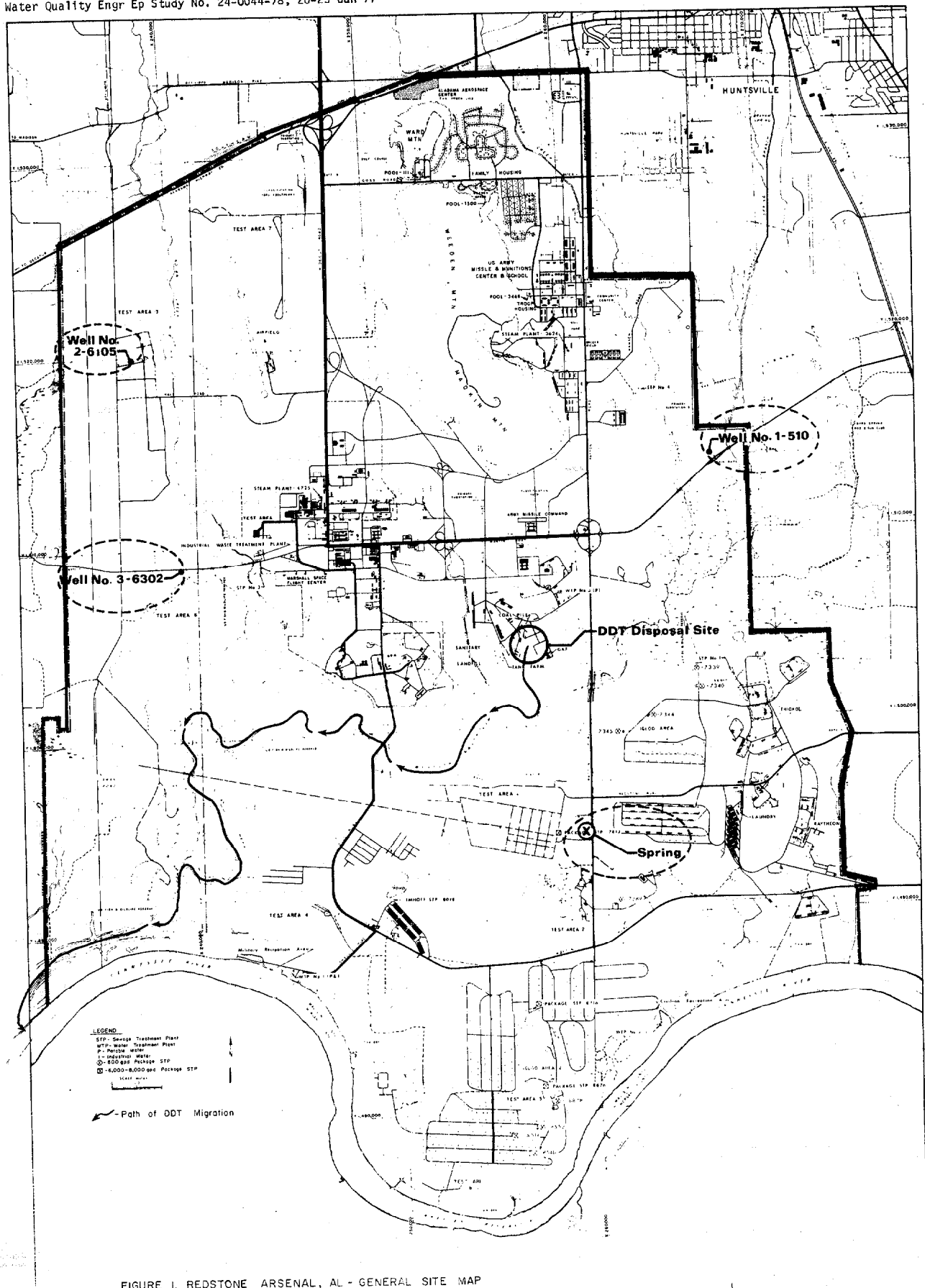


FIGURE 1. REDSTONE ARSENAL, AL - GENERAL SITE MAP

(5) It is apparent from DDT analyses results (see Table 2, Appendix E), that sediment flowing downstream from the disposal site is contaminating the Tennessee River and accumulating in aquatic biota. In order to determine the ambient level of DDT contamination in the river prior to the RSA contribution, samples of water and sediment were collected upstream of Gunter'sville Dam. The analyses of these samples are included in Table 2, Appendix G. No significant levels of DDT contamination were detected.

(6) While background samples yielded no evidence of DDT contamination of the Tennessee River in the vicinity of RSA, this does not mean other sources do not exist. No sampling was performed in the myriad of streams and drainage channels within the major drainage basin, or of agricultural runoff from areas outside the boundaries of RSA.

e. Disposal Site Evaluation.

(1) To evaluate the DDT disposal area, nine sampling sites were excavated and the soil characterized by field observation. Sample site locations are shown in Figure 2. Twenty-three soil samples were taken at various depths at Sample Sites One through Eight, and one ground-water sample was taken at Sample Site Nine.

(2) Two distinct soil strata were noted at the disposal area. A reddish-brown silty clay forms the surface soil stratum which is underlain by a grey clay stratum. A perched water table exists at the interface of these two strata. The perched water flows to the drainage ditch traversing the disposal area.

(3) Analyses results, presented in Table 3, Appendix G, indicate that pockets of high DDTR concentration are located throughout the disposal area, with the o,p'-DDT and p,p'-DDT as the predominant isomers. The high DDTR concentration in the ground-water sample at Sample Site Nine indicates that DDTR could migrate, via the perched ground water, to the surface waters draining the disposal area.

(4) Because of the lack of proper vegetative cover at the disposal area, severe erosion has occurred, exposing previously buried DDT residue. As a result, DDTR is also migrating to surface waters due to surface runoff.

6. CONCLUSIONS.

a. The ground water, other than the perched aquifer beneath the site, is not currently contaminated with DDT.

b. Samples analyzed indicate that fish downstream from the disposal site may be unfit for human consumption. The extent of this contamination is unknown.

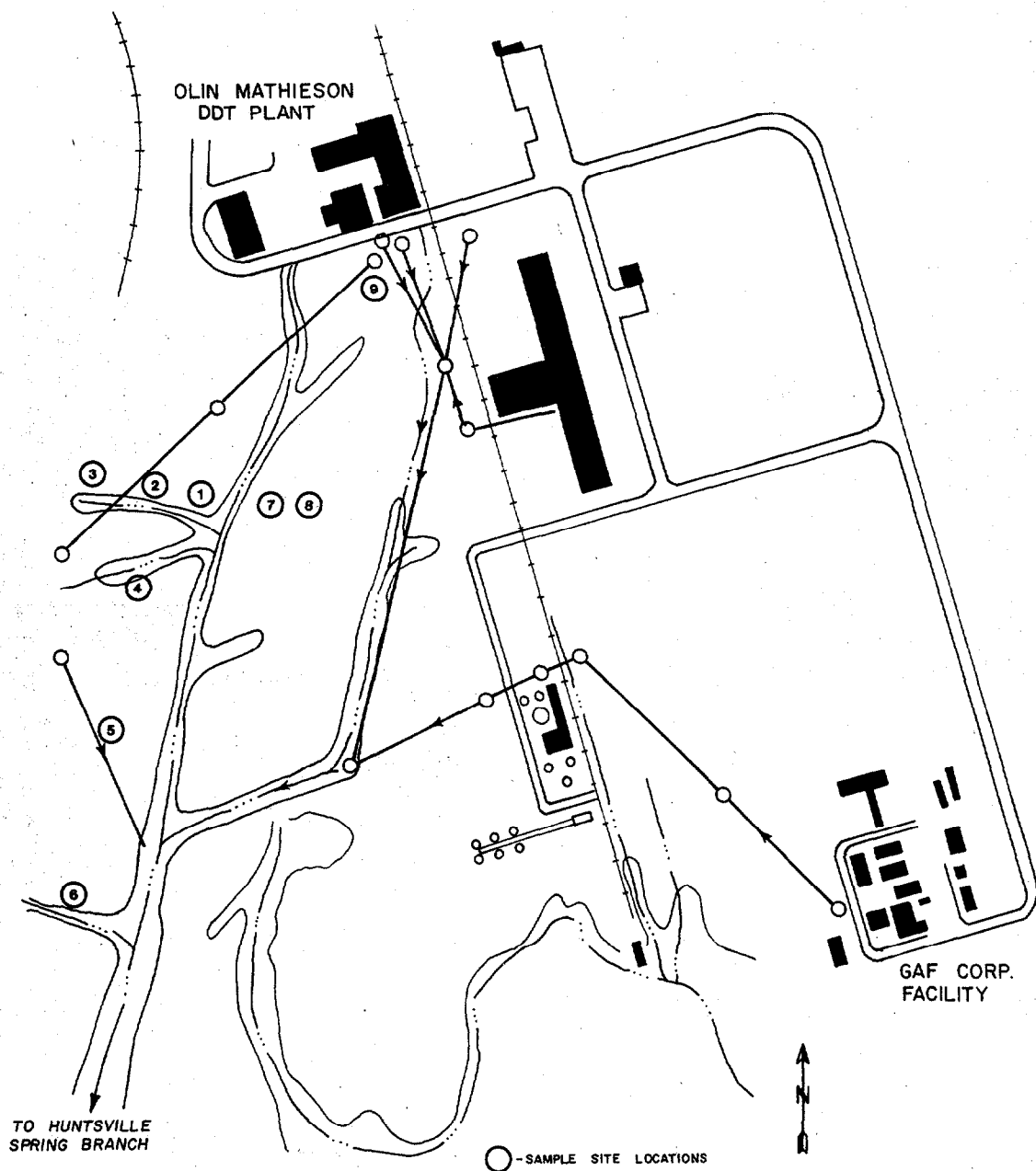


FIGURE 2. SAMPLE SITE LOCATIONS - DDT DISPOSAL AREA

c. The environmental degradation that has occurred due to DDT migration from the disposal site is sufficient to justify corrective measures to control erosion of DDT-contaminated material from the disposal site.

d. High concentrations of DDT exist in the soil in and around the DDT manufacturing site and in the perched aquifer beneath the site.

e. Past measures taken by RSA to control DDT migration were inadequate.

f. Sufficient concentrations of DDT exist in sediment within the drainage system to contaminate the Tennessee River if, during storm periods, this sediment were mobilized by increased storm flow and thus transported downstream to the river.

7. RECOMMENDATIONS.

a. Initiate the following temporary measures to control DDT migration from the disposal site:

(1) Divert all possible storm drainage from the site.

(2) Remove or plug all abandoned sewers within the site.

(3) Grade the site so that no slope greater than 5 percent exists.

(4) Protect all exposed soil surfaces from the impact of falling rain and the energy of runoff water by installing fast-growing grasses or sod blankets.

(5) Cover highly erodible areas with mulch, burlap, or jute netting until grass cover can develop.

(6) Install diversions, berms, flow barriers, or other types of structures which will prevent concentration of runoff in erodible areas.

(7) Construct sedimentation basins in the drainage ditch as it enters Wheeler Wildlife Refuge to facilitate the collection of sediment.

b. Advise public officials that DDT levels in fish from Huntsville Spring Branch and the Tennessee River adjacent to RSA are sufficient to render the fish unfit, by FDA standards, for human consumption.

c. Conduct concentration and flow studies to determine the contaminant loading to the environment and to assess the effects of control measures recommended in paragraph 7a of this report.

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d. Do not attempt to excavate the DDT residual or to core drill the area to determine locations. These actions could puncture the grey clay substratum and provide a direct path of migration to lower aquifers utilized as drinking water sources.

Jerry R Deen
for RICHARD C. KIBLER, P.E.
Sanitary Engineer
Water Quality Engineering Division

John A. Hittlebaugh
JOHN A. HITDLEBAUGH
Sanitary Engineer
Water Quality Engineering Division

APPROVED:

J. Don Gensler
J. DON GENSLER
LTC, MSC
Chief, Water Quality Engineering
Division

APPENDIX A

REFERENCES

1. Proposed Rules, Interim Primary Drinking Water Standards, 40 Federal Register (FR) 11990, 14 March 1975.
2. USEPA-440/9-75-009, Supplement to Development Document, Hazardous Substances Regulations, Section 311 of the Federal Water Pollution Control Act as Amended 1972, November 1975.
3. Drinking Water and Health, Recommendations of the National Academy of Sciences, 42 FR 35764, 11 July 1977.
4. USEPA-540/1-75-022, DDT, A Review of Scientific and Economic Aspects of the Decision to Ban its use as a Pesticide, July 1975.
5. USEPA-440/9-76-023, Quality Criteria for Water, 26 July 1976.
6. Letter, HSE-EW-S, this Agency, 9 August 1977, subject: Special Study No. 24-0044-77, Evaluation of Environmental Degradation from Prior DDT Waste Disposal at Redstone Arsenal, Alabama - Interim Report No. 1.
7. Letter, HSE-EW-S, this Agency, 30 August 1977, subject: Special Study No. 24-0044-77, Evaluation of Environmental Degradation from Prior DDT Waste Disposal at Redstone Arsenal, Alabama - Interim Report No. 2.
8. Letter, HSE-EW-S, this Agency, 13 September 1977, subject: Special Study No. 24-0044-77, Evaluation of Environmental Degradation from Prior DDT Waste Disposal at Redstone Arsenal, Alabama - Interim Report No. 3.

APPENDIX B

ABBREVIATIONS

ca	approximately
DAPMP	Department of the Army Pesticide Monitoring Program
DDD	2,2-Bis (chlorophenyl)-1,1-dichloroethane and related compounds
DDE	1,1-Dichloro-2,2-bis (p-chloro-phenyl) ethylene
DDT	Dichloro diphenyl trichloroethane (mixture of metabolites of ca 80 percent p,p' and 20 percent o,p')
DDTR	A method for totaling the concentration of DDT and its isomers, $DDTR = 1.114 (DDD + DDE) + DDT$
EC	electron capture
EDF	Environmental Defense Fund
FDA	US Food and Drug Administration
g	gram
GLC	gas liquid chromatography
Ha	hectare
mg/kg	milligram per kilogram, a unit of concentration
min	minute
ml	milliliter
mm	millimeter
mV	millivolt
NAS	National Academy of Sciences
PCB	polychlorinated biphenyl
ppb	parts per billion, a unit of concentration
ppm	parts per million, a unit of concentration
ppt	parts per trillion, a unit of concentration
qt	quart
RSA	Redstone Arsenal
TCAN	Trichloroacetonitrile
TDE	DDD
Temp °C	Temperature in degrees Celsius
USAEHA	US Army Environmental Hygiene Agency
USDA	US Department of Agriculture
USEPA	US Environmental Protection Agency
USPHS	US Public Health Service
v/v	volume per unit volume

APPENDIX C

ANALYTICAL PROCEDURES

1. REFERENCES.

a. Pesticide Monitoring Special Study No. 44-0131-77, Pesticide Recovery Studies for Evaluation of DA Pesticide Monitoring Program Soil and Sediment Analysis Methodology - Part I - Determination of Pesticide and Polychlorinated Biphenyls Recoveries from Soil Extracted Immediately Following Fortification, December 1976 (in press).

b. Report, USAEHA, Entomological Special Study No. 44-042-74/75, subject: Extraction and Separation of Polychlorinated Biphenyls from Pesticide Monitoring Samples, 15 April 1975.

2. PESTICIDE MONITORING METHODS OF CHEMICAL ANALYSIS - GENERAL. In support of the Water Quality Engineering Division, the Pesticide Monitoring Branch undertook the analysis of water, soil, sediment, and biological samples obtained at RSA to assess the extent of environmental contamination emanating from an abandoned DDT manufacturing plant.

3. METHODS OF ANALYSIS.

a. Preparation of Samples.

(1) Soil. Upon receipt, samples were placed in refrigerator storage at ca 4°C until extraction. At the time of extraction, the entire soil sample was dumped onto a piece of aluminum foil and mixed. After mixing, a 15-g subsample was weighed into a 1-qt mason jar and carried through the extraction procedure. A separate 50-g subsample was also removed for the determination of soil moisture content. Soil moisture content was determined by placing the 50-g subsample in a foil weighing boat and allowing it to dry at room temperature for 1 week. After this time, the subsample was reweighed and the percent moisture calculated.

(2) Sediment. Upon receipt, samples were placed in refrigerator storage at ca 4°C until extraction. At the time of extraction, the entire sediment sample was emptied into a large Buchner funnel lined with a piece of hexane-extracted filter paper and vacuum filtered until gravitational water was removed. After filtering, the sample was mixed in the Buchner funnel and then a 150-g subsample was weighed into 1-qt mason jar and carried through the extraction procedure. A 50-g subsample was also removed for determination of sediment moisture content using the procedure described above for soil samples.

(3) Fish. Fish samples and all other types of biological samples were maintained at ca -10°C until processing. After thawing, fish samples were thoroughly ground or chopped (depending on the size of the fish) in a Hobart food chopper. After grinding or chopping, the sample was well-mixed prior to subsampling. A subsample (50-g) was weighed into a 1-qt stainless steel blender jar and then extracted. Several samples of less than 50-g were run on small fish or fat body where this amount of tissue could not be obtained. Gar were skinned before grinding.

(4) Birds. After thawing and removal of feet, bills, wings and tails, the birds were skinned. Grinding, mixing, and subsampling procedures for the birds were identical to those described above in paragraph (3) for fish.

(5) Turtle. Turtle samples were shelled and then treated in the same manner as the fish samples. The snapping turtle was extracted minus its intestinal tract. The stomach contents of the snapping turtle were also analyzed using the method for fish.

(6) Frog. Frog samples were treated like fish.

(7) Snake. The sample was prepared by first skinning, then using the routine fish method.

(8) Rabbits. Muscle tissue was removed from each rabbit sample and treated using the routine fish method. Composite samples of liver, brain, fat, and muscle were run using various numbers of the rabbit samples. These tissues were prepared using the method for fish samples.

(9) Water. No special preparation of water samples was carried out prior to extraction. Samples were stored at ca 4°C .

b. Extraction Apparatus and Materials.

(1) Glassware.

(a) 1-qt jars with Teflon®-lined screw caps.

(b) Erlenmeyer flasks - 500 ml, 1000 ml

(c) Glass funnels - 125 mm

© Teflon is a registered trademark of E. I. DuPont de Nemours and Co., Inc.,
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(d) Spatulas, stainless steel

(e) Chromatographic columns - 22x300 mm

(f) Kuderna-Danish Apparatus - 250 ml, 500 ml, 1000 ml flasks, 10 ml concentrator tubes, Snyder columns

(g) Beakers, graduated - 50 ml, 100 ml, 250 ml

(h) Separatory funnels - 125 ml, 500 ml, 1000 ml, 4000 ml

(i) Graduated cylinders - 25 ml, 50 ml, 500 ml, 1000 ml

(j) Chromatographic columns fitted with glass fritted disc - 22x400 mm

(k) Cylindrical separatory funnels with ground glass joint - 500 ml

(l) Centrifuge jars with ground glass stopper - 500 ml

(m) Disposable pipets - 1 ml, 10 ml

(n) Centrifuge tubes, graduated - 15 ml, 40 ml

(o) Culture tubes with Teflon-lined caps - 16x125 mm, 15 ml capacity

(2) Apparatus.

(a) Waring explosion-proof blender

(b) 1-qt stainless steel blender cans with Teflon gaskets

(c) Burrell wrist action shaker

(d) Eberbach variable speed shaker

(e) Mettler balance, top loading

(f) Sartorius balance, analytical

(g) Blue M oven

(h) Desiccator

(3) Reagents, Solvents and Other Supplies.

- (a) Hexane - nanograde
- (b) Petroleum ether - nanograde
- (c) Ethyl ether - nanograde
- (d) Ethyl alcohol - absolute
- (e) Acetonitrile - nonspectro pesticide quality
- (f) Methylene chloride - pesticide quality
- (g) Hydrochloric acid - concentrated - reagent grade
- (h) Sodium sulfate - anhydrous, granular - hexane washed
- (i) Sodium chloride - hexane washed
- (j) Distilled water - hexane washed
- (k) Whatman No. 43 filter paper - preextracted
- (l) Glass wool - silanized - hexane washed

(m) Florisil® - PR grade (60-100 mesh) purchased activated at 1250°F and stored in dark glass containers with foil-lined caps. Activated overnight at 130°C in chromatographic columns prior to use.

c. Soil.

(1) Extraction. After preparation as described above, 15-g subsamples of soil were extracted with 100 ml of 3:1 n-hexane:acetone for 2 hours on a mechanical shaker. After shaking, the samples were allowed to stand for 1 hour to allow settling of particulate matter.

(2) Cleanup.

(a) Chromatographic columns (22x300 mm) containing 4 inches of activated Florisil and 1 inch of anhydrous sodium sulfate were allowed to cool, and then pre-wet with 40-50 ml of hexane. One ml of extract from the previous step was then carefully transferred using a Pasteur pipet onto the Florisil column.

® Florisil is a registered trademark of Floridin Company, P.O. Box 989, Tallahassee, FL.

(b) Graduated beakers (250 ml) were placed under the columns and the columns were eluted with 200 ml of 6 percent ethyl ether/petroleum ether mixture. The beakers were changed and the columns eluted next with 200 ml of 15 percent ethyl ether/petroleum ether mixture. The elution rate for each of the three fractions was maintained at approximately 5 ml/min. NOTE: Ethyl ether used in Florisil column procedure should be free of peroxides and must contain 2 percent v/v of absolute ethanol.

(c) Solvent concentration was done on the 6 and 15 percent fractions to achieve a definitive volume of 160 ml. Extracts were stored in 15 ml screw-cap culture tubes and held in a freezer until gas chromatographic analysis.

d. Sediment.*

(1) Extraction.

(a) After preparation, 150-g subsamples of sediment were extracted with 300 ml of 3:1 n-hexane:acetone for 2 hours on a mechanical shaker. One hour was then allowed for settling of particulate matter.

(b) Using a graduated cylinder, 100-ml aliquots of the sample extracts were measured. The aliquots were then passed through chromatographic columns containing approximately 6 inches of sodium sulfate. The columns were rinsed with 25-30 ml of hexane following elution of the sample extracts. The extracts and rinses were collected in 250-ml Kuderna-Danish apparatus. Extracts were concentrated on a water bath to 10 ml, transferred to 15-ml screw-cap culture tubes, and stored in a freezer until cleanup.

(2) Cleanup.

(a) Chromatographic columns (22x300 mm) containing 4 inches of activated Florisil and 1 inch of anhydrous sodium sulfate were allowed to cool, and then were pre-wet with 40-50 ml of hexane. Sample extracts from the extraction step above were further concentrated to 2-3 ml under a nitrogen stream and carefully transferred using Pasteur pipets onto the Florisil columns. The culture tubes and the sides of the Florisil columns were rinsed with 3 to 5 ml of hexane.

* Several sediment samples with expected high levels of contamination were extracted using the soil method with a 15-g sample size.

(b) Graduated beakers (250 ml) were placed under the columns and the columns were eluted with 200 ml of 6 percent ethyl ether/petroleum ether mixture. The beakers were changed and the columns eluted next with 200 ml of 15 percent ethyl ether/petroleum ether mixture. The elution rate for each of the three fractions was maintained at approximately 5 ml/min. NOTE: Ethyl ether used in Florisil column procedure should be free of peroxides and must contain 2 percent v/v of absolute ethanol.

(c) Solvent concentration was done on the 6 and 15 percent fractions to achieve a definitive volume of 100 ml. Extracts were stored in 15-ml screw-cap culture tubes and held in a freezer until gas chromatographic analysis.

e. Biological Samples.

(1) Extraction.

(a) To a 1-qt stainless steel blender can containing a 50-g subsample of tissue (fish, bird, turtle, snake, etc.) prepared as described above, was added an amount of sodium sulfate equivalent to twice the weight of the sample. As noted in the preparation section, certain samples consisted of whole organisms or parts of organisms that weighed more or less than 50-g. This is taken into account when results are calculated.

(b) Samples were then extracted using a high speed blender with successive 150-ml, 100-ml and 100-ml portions of petroleum ether. After each extraction, the supernatant petroleum ether was filtered by gravity through glass funnels lined with preextracted filter paper into 1000-ml round bottom flasks. After the petroleum ether extractions, the residues from the blender jars were transferred to the glass funnels and the jars and residue were rinsed with several small portions of petroleum ether. The rinses were combined with the petroleum ether extracts in the 1000-ml round bottom flasks.

(c) The combined petroleum ether extracts and rinses were passed through chromatographic columns (22x300 mm) containing 6 to 8 inches of anhydrous sodium sulfate. The flasks and columns were rinsed with a small portion of hexane. Extracts and rinses were collected in 1000-ml Kuderna-Danish apparatus.

(d) The sample extracts were concentrated on a water bath to 10 ml. After concentration, the extracts were transferred to previously weighed 50-ml beakers, and evaporated under a gentle nitrogen stream until all solvent was removed. The resulting fat material was weighed (resulting fat weights for most biological samples ranged from 0.5 g to 3.0 g) and then transferred using Pasteur pipets and small measured amounts of petroleum ether carrier solvent into 125-ml separatory funnels. Additional petroleum

ether was added to the separatory funnels so that the total volumes of fat and petroleum ether were 15 ml.

(e) The petroleum ether-fat extract solutions were extracted successively with four 30-ml portions of acetonitrile saturated with petroleum ether. The separatory funnels were shaken vigorously for 1 minute during each extraction. Following each extraction, the acetonitrile layers were drained into 1000-ml separatory funnels containing 650 ml of water, 40 ml of saturated sodium chloride solution and 100 ml of petroleum ether.

(f) The 1000-ml separatory funnels containing the combined extracts from the four acetonitrile extractions were shaken moderately for 30 to 40 seconds. Following separation of layers, the aqueous layers were drained into second 1000-ml separatory funnels. Petroleum ether (100 ml) was added to the second separatory funnels and the funnels were shaken vigorously for 15 to 30 seconds. The layers were allowed to separate and then the aqueous layers were discarded. The petroleum ether layers in the second separatory funnels were combined with the petroleum ether layers in the original separatory funnels, and the combined petroleum ether layers were washed with two successive 100-ml portions of water. The aqueous layers were discarded between washings.

(g) The petroleum ether extracts from step (f) above were passed through chromatographic columns containing 6 to 8 inches of anhydrous sodium sulfate. The separatory funnels and columns were rinsed with 3- to 10-ml portions of petroleum ether. The extracts and rinses were collected in 500-ml Kuderna-Danish apparatus. The extracts were concentrated to 10 ml, transferred to 15-ml screw-cap culture tubes, and stored in a freezer until cleanup.

(2) Cleanup. The sample extracts from extraction step (g) above were further concentrated under nitrogen to 2 to 3 ml, and then transferred to Florisil columns. The procedure used for Florisil column cleanup of the fish, bird, and other biological samples were identical to those previously described for soil and sediment, except that each of the three eluate fractions were collected in 500-ml Kuderna-Danish apparatus, and then concentrated to 10 ml. The 6 percent eluates were transferred to screw-cap culture tubes and stored in a freezer until processing through the silicic acid column separation procedure described below. The 15 percent eluates were transferred to culture tubes and held for gas chromatographic analysis.

(3) Silicic Acid Column Separation Procedure. The 6 percent eluates from the Florisil cleanup procedure were processed directly, without preliminary gas chromatographic screening, through the silicic acid column separation procedure. SilicAR® CC-4 special for column chromatography is

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prepared for use as follows: SilicAR was placed in enamel pans covered with aluminum foil and heated in an oven at 130°C for 24 hours or longer. The SilicAR was deactivated by first weighing 100 g into a glass centrifuge bottle. The bottle was then sealed and allowed to cool to room temperature in a desiccator. Once at room temperature, 3 ml of water were added. The centrifuge bottle was then tightly stoppered and shaken on a wrist action shaker for a period of 4 hours. The centrifuge bottle was then returned to the desiccator and allowed to equilibrate for 15 hours. Desired activity was retained for about 5 days if stored in a desiccator.

(a) Silicic acid columns were prepared as follows: silicic acid (20 g), deactivated as described above was weighed into a 250-ml beaker and immediately slurried with 80 ml of petroleum ether. The slurry was quickly poured through a long-necked glass funnel onto a chromatographic column (22x400 mm) with stopcock open. The glass funnel and the sides of the column were washed down with additional small portions of petroleum ether. While gently tapping the column with a wooden ruler, the petroleum ether was allowed to drain through the column until the level of petroleum ether was about 3 mm above the surface of the silicic acid. The column stopcock was then closed.

(b) The 6 percent eluate fractions from cleanup step (a) were further concentrated to about 2 to 3 ml under a nitrogen stream. A 500-ml graduated cylinder was placed under the silicic acid columns. The concentrated eluate fractions were then slowly and carefully pipetted onto the columns using long-stemmed Pasteur pipets. The column stopcocks were opened and the solvent level drained to 3 mm. Three additional 2-ml rinse aliquots of petroleum ether were pipetted onto the columns, slowly washing down the sides of the columns. After the addition of each 2-ml petroleum ether aliquot, the solvent level was drained to 3 mm. The column stopcocks were then closed and an additional 10 ml of petroleum ether pipetted onto each column. A cylindrical separatory funnel containing 400 ml of petroleum ether was placed on the top of each column, the stopcocks were opened and petroleum ether elutions (at the rate of approximately 5 ml/min) were commenced. Elutions were continued until exactly 400 ml of petroleum ether eluate was collected in the 500-ml graduated cylinders. These eluates comprised combined silicic acid column fractions I and II. The column stopcocks were closed and 200 ml of a 1:19:80 acetonitrile:n-hexane:methylene chloride mixture were added to the cylindrical separatory funnels. A 500-ml Kuderna-Danish apparatus was placed under each column, the stopcocks were opened, and elutions of the above mixture (5 ml/min) were commenced. The columns were allowed to elute to dryness. The resulting eluates comprised silicic acid column fraction III.

(c) The combined silicic acid column fraction I and II eluates were transferred to 1000-ml Kuderna-Danish apparatus and concentrated to 10 ml. The concentrated I and II eluates were transferred to 15-ml screw-cap culture

tubes, and stored in a freezer until gas chromatographic analysis. The silicic acid column fraction III eluates were concentrated in the 500-ml Kuderna-Danish apparatus to 10 ml. The eluates were transferred to 15-ml screw-cap culture tubes and stored in a freezer until gas chromatographic analysis. At the time of gas chromatographic analysis, the fraction III eluates were diluted 1:20 to obtain an appropriate definitive volume.

(4) Water Samples - Extraction. The pH of water samples was first adjusted to near neutral (pH 6.5-7.5), if necessary with 50 percent sulfuric acid or 10 normal sodium hydroxide. Five hundred ml of each sample were then quantitatively transferred into separate 2-liter separatory funnels and diluted to 1-liter with hexane extracted distilled water. Sixty ml of 15 percent methylene chloride in hexane (v/v) was added to each sample in the separatory funnels and shaken vigorously for 2 minutes. The mixed solvent was allowed to separate from the samples. After separation, the aqueous layer of each sample was drawn into a 1-liter erlenmeyer flask. The remaining organic layer of each sample was transferred to a respective 100-ml beaker and then passed through separate chromatographic columns containing 3 to 4 inches of anhydrous sodium sulfate. The extracts were collected in separate 500-ml Kuderna-Danish apparatus equipped with 10-ml concentrator tubes. Water phases were returned to their separatory funnels. A second 60-ml volume of solvent was added to each erlenmeyer flask and rinsed. Respective rinse solvents were poured into each separatory funnel and extraction was conducted as stated above. A third extraction was conducted in the same manner. Sample extractions were concentrated on a hot water bath at 100°C to 5 ml and stored in 15-ml screw-cap culture tubes for gas chromatographic analysis. No cleanup was required for the water samples.

4. GLC PARAMETERS AND TECHNIQUES.

a. Instrumental Parameters.

(1) Gas Chromatographs.

(a) Tracor® 220.

(b) Tracor 222.

(c) Tracor 560.

(2) Detectors.

(a) High temperature NI⁶³ EC detector - used for detection or organochlorine pesticides.

(b) Coulson electrolytic conductivity detector - used as confirmatory detector for organochlorine pesticides.

® Tracor is a registered trademark of Tracor, Inc., Austin, TX.

(3) Gas Chromatographic Columns.

(a) 1.5 percent OV-17/1.95 percent QF-1 on 80/100 Gas Chrom Q.

(b) 3 percent OV-1 on 80/100 Gas Chrom Q.

(c) 5 percent OV-210 on 80/100 Gas Chrom Q.

(4) Recorder. Honeywell Elektronik Potentiometric Strip Chart (1 mV).

(5) Routine Analysis Parameters for GLC.

(a) Oven Temperatures: 200°C [used with columns (1) and (2)]
185°C [used with column (3)]

(b) Injection port temperature: 200-225°C

(c) Outlet temperature (if applicable): 240°C

(d) Detector temperatures: EC-300°C

(e) Carrier gas flows: EC columns (95 percent Argon-5 percent Methane)
- 60-70 ml/min

Coulson column (nitrogen) - 60 ml/min

(f) Detector gas flows: Coulson - hydrogen (80 ml/min) - nitrogen (60 ml/min)

b. GLC Quantitation Methods - Automatic Integration Method. Automatic integration of peak areas was carried out using an AutoLab System IV Computing Integrator (Spectra-Physics, Mountain View, CA). This method of quantitation was employed for all organochlorine pesticides. The 1.5 percent OV-17/1.95 percent QF-1 column (coupled to an EC detector) was used for these quantitations.

c. GLC Confirmation Techniques.

(1) Approximately 10 percent of positive pesticide GLC results were confirmed by one or both of the GLC confirmatory techniques described below.

(2) GLC results were confirmed by the following two techniques:

(a) Comparisons of retention times of sample pesticide peaks and reference standard peaks on an alternate column. For confirmations of organochlorine pesticide results, the 5 percent OV-210 and, to a lesser extent, the 3 percent OV-1 columns were used as alternate columns.

(b) Comparisons of retention times and quantitative responses for organochlorine pesticide sample peaks and reference standard peaks using the halogen specific Coulson electrolytic conductivity detector.

5. QUALITY CONTROL PROCEDURES.

a. Use of Standardized and Validated Analytical Methodology.

(1) Soil and Sediment Samples. Extraction and cleanup procedures used for these samples were identical to the basic procedures used in the DAPMP for extraction and cleanup of soil and sediment routinely received under this program. A complete discussion and results of initial pesticide recovery studies for DAPMP soil and sediment analysis methodology are presented in reference 1, Inclosure 1.

(2) Fish, Birds, and Other Biological Samples. Extraction and cleanup procedures employed for these samples were adapted from widely-used FDA methodology designed for the determination of pesticides and other chemicals in fatty foods.¹ This FDA methodology is presently being used for laboratory extraction and cleanup of fish and birds samples routinely received under the DAPMP.

(3) PCB Separation Procedure. The silicic acid column separation procedure of the US Fish and Wildlife Service Patuxent Laboratory was used in the present study.² This procedure is currently in routine use in the DAPMP (reference 2).

(4) Water Extraction. The methodology used for the extraction of organochlorine pesticide (i.e., DDT and its metabolites) from RAS water samples was based on the method in industrial effluents.³

(5) Sample Description. Appropriate sample and reagent blanks and controls, as required by the above-referenced methodology, were used throughout the present study.

¹ Pesticide Analytical Manual, Volume 1, Methods Which Detect Multiple Residues, USDHEW, FDA (revised July 1975)

² Analytical Manual - Patuxent National Wildlife Research Laboratory, USDI, Fish and Wildlife (1975)

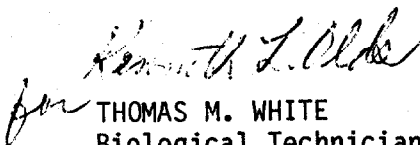
³ Method for Organochlorine Pesticides in Industrial Effluents, National Pollutant Discharge Elimination System, Appendix A, Fed. Reg., 38, No. 75, Pt. II.

(6) USEPA Fat Check Sample. A sample of chicken fat, fortified with known amounts of organochlorine pesticides and a PCB, is received at regular intervals from USEPA for use as an intralaboratory check sample for validation of routine DAPMP fish and bird analyses. This check sample was analyzed periodically along with fish, bird, and other biological samples received from RAS as a means of intralaboratory control. The results of four replicate analyses of the check sample are summarized in the Table. Recoveries were excellent for the check sample, with a mean of 91.2 percent for p,p'-DDE and 87.5 percent for p,p'-DDT.

5. LIMITS OF DETECTABILITY FOR DDT AND ITS ISOMERS. Limits of detectability in the various substrates analyzed from RAS are reported in the tables of results throughout this report.



JACK M. HELLER, Ph.D.
Entomologist
Pest Management & Pesticide
Monitoring Division


for

THOMAS M. WHITE
Biological Technician
Pest Management & Pesticide
Monitoring Division

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TABLE. RESULTS OF FOUR REPLICATE ANALYSES OF USEPA FORTIFIED CHICKEN FAT INTRALABORATORY CHECK SAMPLE

Replicate No.	(Pesticide or PCB Results (ppm))						
	p,p'-DDE	p,p'-DDT	Oxychlordane	Heptachlor Epoxide	-BHC	Aldrin	Aroclor® 1260
1	2.29	0.34	0.14	0.19	0.21	0.15	2.17
2	2.17	0.38	0.12	0.18	0.19	0.19	2.04
3	2.63	0.34	0.15	0.25	0.20	0.29	2.39
4	2.04	0.33	0.11	0.20	0.17	0.19	2.06
X (all replicates)	2.28	0.35	0.13	0.21	0.19	0.21	2.17
Actual Fortification Levels	(2.50)	(0.40)	(0.15)	(0.20)	(0.20)	(0.20)	(2.00)
Average Percent Recovery (all replicates)	91.20	87.50	86.67	105.00	95.00	105.00	108.50

APPENDIX D

REGULATORY STATUS OF DDT AND CURRENT ENVIRONMENTAL MONITORING DATA

1. CANCELLATION OF THE REGISTRATION OF DDT AND CLOSELY RELATED PESTICIDES.

a. The registration of all products containing DDD, also known as TDE, was cancelled by Pesticide Regulation Notice 71-5, 18 March 1971. The registration of all products containing DDT was cancelled by Pesticide Regulation Notice 71-1 on 15 January 1971 and by the USEPA Administrator in his action of 7 July 1972, 37 FR 13369.

(1) The following list of users were specifically exempted from these actions.

(a) The USPHS and other Health Service officials for control of vector diseases.

(b) The USDA or Military for health quarantine.

(c) In drugs for controlling body lice. (To be dispensed only by physician.)

(d) In the formulation for prescription drugs for controlling body lice.

(2) These cancellation actions were initiated after extensive public hearings and the action of the Administrator represented an overriding of the recommendations of the Hearing Examiner (now referred to as Administrative Law Judge).

b. None of these administrative actions were initiated on the basis of an acute hazard to human health but rather from an opinion of the US District Court of Appeals, District of Columbia, EDF V Ruckelshaus, "... that the most important element of an imminent hazard to the public" is a serious threat to public health, that a hazard may be 'imminent' even if its impact will not be apparent for many years, and that the 'public' protected by the suspension provision includes fish and wildlife."

c. There are still in force a variety of tolerances for DDT in or on raw agricultural commodities.

2. SIGNIFICANCE OF DDT AND ITS METABOLITES IN THE ENVIRONMENT.

a. Present day analytical technology makes it possible to detect DDT in extremely low concentrations (ppb) in nearly all components of the environment, if a sufficiently large sample size is collected and processed.

b. In view of the philosophical impossibility of establishing the absolute lack of any adverse consequence, it is generally regarded as prudent to terminate further introductions of this pesticide into the environment, unless there is a demonstrable immediate unique benefit from its use.

3. OCCURRENCE OF DDT AND ITS METABOLITES IN THE ENVIRONMENT.

a. The DAPMP became fully operational during CY1975 with a statistically stratified environmental sampling plan. DDT and metabolites are among the pesticides on the routine pesticide monitoring list. A contrast of the general environment as represented by data from the DAPMP with specific data from limited sampling at RSA indicates the nature of the problems at and around this former DDT manufacturing site. A summarization of these data appear in the Table.

b. The following segments of the environment in and around RSA are excessively contaminated with DDT and certain of its metabolites:

(1) Soil in and around the former DDT manufacturing area.

(2) Sediment downstream from this manufacturing site.

(a) In the ravine more or less traversing the site.

(b) In the Wheeler Wildlife Refuge formed largely from the Huntsville Spring Branch of the Tennessee River.

(3) In various species of fish taken within the wildlife refuge area and in the Tennessee River in the general vicinity of the confluence of the Huntsville Spring Branch and the Tennessee River.

(a) Data summaries derived from analysis of whole fish suggest that populations taken in the area of the wildlife refuge are in general more contaminated than populations taken from the Tennessee River. Analysis of variance does not support this hypothesis.

(b) All of the data are based on single fish samples rather than samples comprised of five or more fish.

c. The presence of DDT per se in the bird samples contrasts sharply with the general bird monitoring data from the DAPMP where p,p'-DDE is the only DDT related residue detected.

(1) General avian monitoring data are based on starlings as the major component in contrast to a variety of species obtained from the RSA area.

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TABLE. 1977 REDSTONE ARSENAL DDT MONITORING DATA CONTRASTED WITH 1975 DAPMP DATA

		No. Samples	op'-DDD	pp'-DDD	op'-DDE	Average ppm pp'-DDE		op'-DDT	pp'-DDT	DDTR
Soil*	RSA	25	96	1114	90	828	2258	33847	38462	
	DAPMP	697	.2	1.2	.02	.8	2.4	39.3	44	
Sediment	RSA	25	24	36	12	29	34	290	438	
		363	.06	.2	.005	.03	.004	.05	.41	
Fish†	RSA	33	5.9	22.4	3.8	12.8	.9	1.33	49	
	DAPMP	56	.02	.14	nd	.17	.001	.01	.40	

* DAPMP soil samples are composites from 1/2 Ha sites.

RSA samples are not composites.

† RSA Individual Fish

DAPMP Composite Samples

(2) The overall mean DDE residue in starlings from other CONUS installations for 1975 was 0.797 ppm DDE, in contrast to the mean residue data for a variety of species from RSA of 17 ppm DDE.

(3) Until more extensive data become available from other pesticide monitoring programs, these relatively high DDT residues in the bird species sampled should be regarded as related to the high DDT residues in a localized area within RSA.

d. The data available indicate it is unlikely that any significant contamination exists in surface water, other than that associated with suspended organic particulate matter.

e. There is no evidence of significant DDT contamination of ground waters in the area.

f. Prompt termination of further erosive contamination of the aquatic environment of Wheeler Wildlife Refuge would permit this area and the downstream areas of the Tennessee River to revert, in less than 5 years, to a DDT profile similar to that characteristic of streams traversing agricultural areas.

Clifford C. Roan
CLIFFORD C. ROAN, Ph.D.
Chief, Pesticide Monitoring Branch
Pest Management and Pesticide
Monitoring Division

APPENDIX E

ECOLOGICAL ASSESSMENT OF DDT DISCHARGE

1. BACKGROUND.

a. Historical information on the DDT plant operation is presented in the main body of this report.

b. Huntsville Spring Branch, as a portion of the Wheeler National Wildlife Refuge, is currently monitored by personnel from the refuge. Several fish kills have been observed accompanying periods of low oxygen levels in the stream. Refuge personnel indicated that both industrial and domestic discharges have severely damaged the stream.¹ Some recovery was noted due to the closing of the DDT plant and upgrading of the City of Huntsville Sewage Treatment Plant.

2. ASSESSMENT RATIONALE.

a. The pathways of accumulation of residues of DDT and its principal metabolites, DDD and DDE, in the various segments of our environment have been extensively studied. An excellent summary of this data is present in Edwards (1973).² The biological vulnerability to DDTR accumulation by an individual species or population is a function of a number of interacting relationships that include:

- (1) The behavior of the insecticide upon reaching the environment.
- (2) The life requirements or ecological niche of the species.
- (3) The frequency of ecological incidence of individual organisms with the contaminant.
- (4) The level of prior residue accumulation of the insecticide or other toxins.

¹ Personal Communication Thomas Z. Atkeson (Refuge Manager, Wheeler National Wildlife Refuge (26 May 1977)

² C. A. Edwards, Persistent Pesticides in the Environment (2d Ed.), CRC Press (1973)

(5) The innate behavior of the species in relation to physiological processes such as lipid utilization.

(6) Variations in these relationships brought about by differences in environmental factors, such as food availability, weather, pollution stress, and habitat conditions.

b. A model migration/accumulation scheme for DDTR is given in the Figure. The significance of accumulation and migration up the food chain is the potential threat to man and other species which are dependent upon the aquatic ecosystem. Levels of accumulation are also indicative of the extent of ecological damage due to chronic and/or acute toxicity.

3. FINDINGS AND DISCUSSION.

a. Tables 1 and 2, this Appendix, present DDTR accumulation data for fish from Huntsville Spring Branch and the Tennessee River. The FDA has established an administrative guideline of 5 ppm DDTR for raw edible fish tissue.³ All of the fish from Huntsville Spring Branch and all second or third trophic level fish from the Tennessee River (bass, gar, and catfish) exceeded this level in whole body analysis. Taking into account fat deposits within muscle tissue (see sample Nos. 3, 4, 10, and 11, Table 1) and the high total body concentration, there is no doubt that these fish exceed FDA guidelines for edible tissue.

b. Table 3 of this Appendix presents bird, reptile, amphibian, and mammal data from the DDT plant site. Those organisms which are carnivorous have accumulated higher body burden than the herbivores. Since those organisms normally eaten by man (e.g., rabbit, dove, and quail) do not have excessively high body burdens, a direct threat to man for consumption is not indicated. However, the fact that land animals have such body burdens gives added proof of continued DDTR from the site and gives impetus to the need for greater containment of the contaminant.

c. The extensive ecological damage which is caused by DDTR is well documented.⁴ DDT is detrimental and/or toxic to each trophic level of the aquatic ecosystem. Exposure to low levels of DDTR has resulted in a 90 percent reduction of oxygen production capability in some species of algae.

³ Guidelines, FDA, No. 7420.09, Attachment F (13 September 1974)

⁴ USEPA-540/1-75-022, DDT, A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide (July 1975)

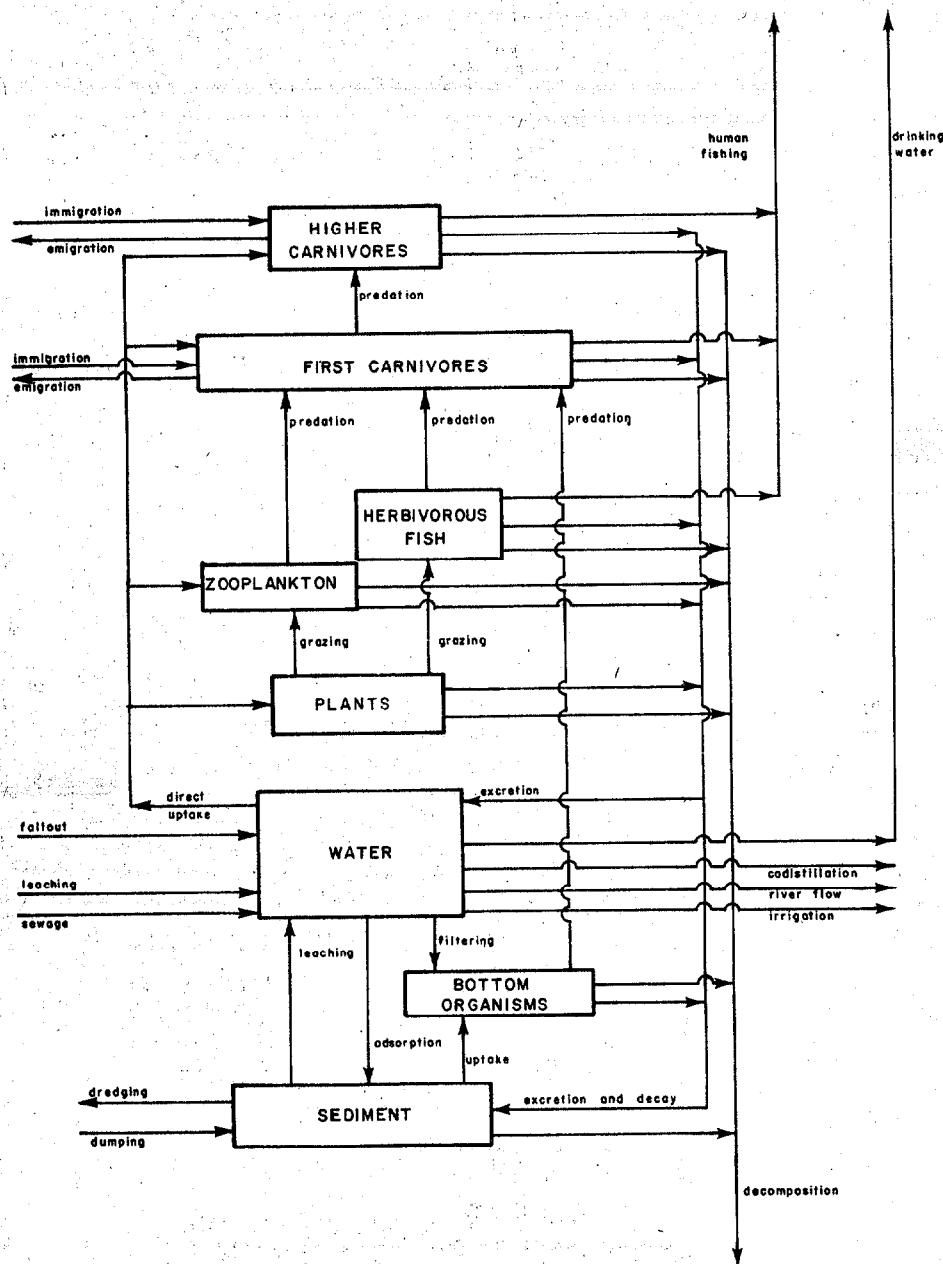


FIGURE. DDTR MIGRATION/ACCUMULATION SCHEMATIC

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TABLE 1. ANALYTICAL RESULTS - FISH SAMPLES, HUNTSVILLE SPRING BRANCH (QUANTITIES EXPRESSED AS ppm)*†

Sample No.	Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR
1	Gar - 25 g flesh with fat bodies removed	22.72	73.38	16.68	48.72	9.38	13.61	202.90
2	Gar - 1.8 g fat extracted from flesh sample No. 1	315.58	1019.14	231.65	676.65	130.22	189.04	2817.98
3	Gar - 7.5 g fat bodies	65.66	229.26	37.70	138.63	29.30	36.74	591.21
4	Gar - fat extracted from fat bodies	281.41	982.52	162.33	594.14	125.55	157.45	2533.75
5	Gar, short nose - whole fish	19.00	67.53	13.19	48.89	11.90	16.47	193.92
6	Goldfish - whole fish Composite - 4 fish	9.47	34.94	8.32	39.31	5.74	3.13	111.40
7	Black Crappie - whole fish, Composite - 2 fish	11.14	26.95	3.98	10.41	2.15	2.52	63.13
8	Blue Gill/Redear Sunfish - whole fish, Composite - 2 fish	2.24	10.66	1.37	4.07	0.26	0.70	21.39
9	Fresh Water Drum - whole fish	5.11	19.32	8.97	20.64	ND	0.12	60.32
10	Channel Cat - flesh with fat bodies removed	18.40	57.98	8.14	19.75	ND	0.44	116.60
11	Channel Cat - fat bodies from sample No. 9	137.31	428.06	61.03	153.48	ND	3.34	872.13
12	Gizzard Shad - whole fish Composite - 4 fish	15.99	49.17	10.74	36.08	ND	2.28	127.00
13	White Bass - whole fish	18.61	44.45	6.10	25.16	ND	.46	105.53

* Detection Level - 0.01 ppm

† Samples were collected in area indicated as sample point No. 2 identified in reference 8, Appendix A.

Jack M. Heller
 JACK M. HELLER, Ph.D.
 Entomologist
 Pest Management & Pesticide
 Monitoring Division

TABLE 2. ANALYTICAL RESULTS - FISH SAMPLES FROM TENNESSEE RIVER ADJACENT TO REDSTONE ARSENAL (QUANTITIES EXPRESSED IN ppm)*†

Sample No.	Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR
1	Channel Catfish - whole fish	0.74	3.06	0.25	4.46	ND	ND	9.48
2	Channel Catfish - whole fish	37.55	225.73	22.68	78.97	2.32	2.75	411.60
3	Blue Gill - whole fish	2.73	17.37	3.26	8.25	ND	ND	35.21
4	Redear Sun Fish - whole fish	0.52	2.52	0.82	2.38	ND	ND	6.95
5	Redear Sun Fish - whole fish	0.09	0.57	0.30	1.33	ND	ND	2.55
6	Green Sun Fish - whole fish	0.44	4.12	1.09	4.15	ND	ND	10.92
7	Redear Sun Fish - whole fish	0.14	0.99	0.23	0.01	ND	0.13	2.77
8	Redear Sun Fish - whole fish	ND	0.14	ND	0.26	ND	0.02	0.47
9	Redear Sun Fish - whole fish	0.02	0.17	0.02	0.14	ND	ND	0.39
10	Redear Sun Fish - whole fish	0.53	4.13	0.78	2.47	ND	0.17	8.98
11	Longear Sun Fish - whole fish	0.02	0.36	0.06	0.06	ND	ND	0.98
12	Blue Gill - whole fish	ND	0.30	0.05	0.56	ND	0.02	1.03
13	Blue Gill - whole fish	ND	3.11	0.63	4.48	ND	0.48	9.64
14	Redear Sun Fish - whole fish	0.02	0.16	ND	0.43	ND	ND	0.68
15	Blue Gill - whole fish	0.54	4.86	1.31	10.87	ND	0.25	19.29
16	Blue Gill - whole fish	ND	0.42	ND	0.54	ND	ND	1.07
17	Bass - whole fish	0.69	2.34	0.84	3.56	0.13	0.11	8.52
18	Bass - whole fish	40.75	110.81	17.83	48.11	6.14	11.28	259.72
19	Bass - whole fish	13.74	43.62	8.60	24.65	1.27	1.32	103.53
20	Bass - whole fish	1.59	4.99	1.37	4.02	ND	0.06	13.39
21	Bass - whole fish	8.25	25.90	4.50	11.21	ND	0.42	55.96
22	White Bass - whole fish	0.13	1.9	0.45	3.8	ND	ND	6.28
23	Flat Head Catfish - whole fish	1.1	7.9	0.92	4.7	ND	ND	14.62
24	Flat Head Catfish - whole fish	2.5	14.2	3.4	7.43	ND	0.11	30.78
25	Flat Head Catfish - whole fish	0.87	7.38	1.9	8.9	ND	ND	21.22
26	Gar - whole fish	89.95	278.80	31.99	138.12	2.68	13.07	616.04

* Detection Level - 0.01 ppm

† Samples were collected in area indicated as sample point No. 1 identified in reference 8, Appendix A.

Jack M. Heller
 JACK M. HELLER, Ph.D.
 Entomologist
 Pest Management & Pesticide
 Monitoring Division

TABLE 3. ANALYTICAL RESULTS - BIRD, REPTILES, MAMMALS FROM DDT PLANT SITE (QUANTITIES EXPRESSED IN ppm)*

Sample No.	Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR
1	<u>Zenaidura macroura</u> - Morning Dove	ND	0.56	ND	0.38	ND	3.21	4.25
2	<u>Agelaius phoeniceus</u> - Redwing Blackbird	ND	0.14	0.53	19.20	ND	0.21	22.35
3	<u>Agelaius phoeniceus</u> - Redwing Blackbird	ND	1.13	0.12	64.19	ND	3.79	76.690
4	<u>Colaptes auratus</u> - Yellow-Shafted Flicker	ND	0.05	ND	8.12	ND	0.41	9.51
5	<u>Molothrus ater ater</u> - Brown-Headed Cowbird	ND	0.14	0.07	7.20	ND	0.23	8.48
6	Fringillidae - Species Unknown - Sparrow	ND	0.133	0.084	16.17	ND	.573	18.83
7	<u>Geothlypis trichas</u> - Yellow Throated Warbler	ND	0.14	ND	14.67	ND	0.35	16.87
8	Vireonidae - Species Unknown - Vireo	ND	0.04	ND	9.13	ND	ND	10.22
9	<u>Colinus virginianus</u> - Bob White Quail	ND	ND	ND	9.50	ND	ND	10.58
10	<u>Riparia riparia riparia</u> - Barn Swallow	ND	0.04	ND	0.75	ND	ND	0.91
11	<u>Turdus migratorius</u> - Robin	ND	ND	ND	1.07	ND	0.02	1.23
12	<u>Chelydra serpentina</u> - Snapping Turtle	0.48	4.58	ND	42.53	ND	4.64	57.65
13	Stomach content, sample No. 12	7.55	8.44	4.10	8.09	1.06	2.46	34.91
14	<u>Rana catesbeiana</u> - River Frog	0.02	0.38	ND	1.82	0.13	1.79	4.39
15	<u>Terrapene carolina carolina</u> - Eastern Box Turtle	ND	0.12	ND	0.44	0.16	0.59	1.37
16	<u>Seminatrix pygaea</u> -† Black Swamp Snake	7.28	88.4	2.46	116.28	ND	6.7	245.56
17	<u>Sylvilagus floridanus</u> - Composite Muscle Tissue - 2 Adult, 3 Juvenile Cottontail Rabbits	ND	0.032	ND	0.15	ND	0.099	0.30
18	Composite liver sample from sample No. 17	ND	0.32	ND	0.74	ND	ND	1.18
19	Composite brain sample from sample No. 17	ND	ND	ND	0.23	ND	0.14	0.40
20	<u>Sylvilagus floridanus</u> - Cottontail Rabbit, Juvenile, muscle tissue	ND	ND	ND	0.088	ND	0.0355	0.13

* Detection Limit - 0.01 ppm

† Collected from junction of DDT ditch and Huntsville Spring Branch

Jack M. Heller
 JACK M. HELLER, Ph.D.
 Entomologist
 Pest Management & Pesticide
 Monitoring Division

This factor and heavy organic loading have resulted in periods of oxygen depletion in sections of Huntsville Spring Branch. As would be expected, DDTR is highly toxic to most aquatic invertebrates (insects, clams). Experimental data have also indicated reproductive failures and other sublethal effects at very low levels of DDTR. Reduction in suitable habitat and food supply plus toxicity to less tolerant species have severely lowered the diversity of fish capable of surviving in upper Huntsville Spring Branch.

d. Migration of organisms, both terrestrial and aquatic, results in considerable displacement of DDTR away from the site of introduction. Such migrations present additional problems due to the extensive acreage of Wheeler National Wildlife Refuge adjacent to the DDT disposal site. Levels of DDTR in fish from the Tennessee River show the extent of contaminant migration, presenting two potential problems: first, consumption by man of migrating contaminated fish throughout the refuge, and second, further accumulation in overwintering Canadian geese and other water fowl which utilize the refuge. Three species of nationally protected endangered piscivorous birds (bald eagle, osprey, and peregrine falcon) are thought to utilize or potentially utilize the refuge. Egg-shell thinning and impaired reproductive success due to DDTR have been cited as the causes for decline of these species. Less than 1 ppm DDE in their diet causes significant thinning of shells.⁴ DDTR accumulation also presents an extreme hazard to migratory birds due to utilization of fat reserves during the long flight. DDTR is relocated through the bloodstream and accumulates in the brain, causing death.

4. CONCLUSIONS.

a. DDTR has accumulated in fish from Huntsville Spring Branch and the adjacent Tennessee River in excess of level considered safe for human consumption by FDA standards.

b. Extensive ecological damage due to DDTR has occurred in Huntsville Spring Branch and the Tennessee River adjacent to RSA.

c. Extensive biological migration of DDTR into the Wheeler National Wildlife Refuge has occurred. Potential for extensive damage to the refuge fauna is present.

d. DDTR contamination of the terrestrial food chain is ongoing at the DDT disposal site.

⁴ USEPA-540/1-75-022, DDT, A Review of Scientific and Economic Aspects of the Decision to Ban Its Use as a Pesticide (July 1975)

5. RECOMMENDATIONS.

- a. Advise public officials that DDT levels in fish from Huntsville Spring Branch and the Tennessee River adjacent to RSA are sufficient to render the fish unfit, by FDA standards, for human consumption (paragraph 4a, this Appendix).
- b. Determine the extent of migration of DDTR into the Wheeler National Wildlife Refuge (paragraph 4d, this Appendix).
- c. Prevent further contamination of the environment by proper containment of pesticide contaminants from the DDT disposal site (paragraph 4b, this Appendix).

for Henry C. Eichen
DAVID W. SMITH
Aquatic Biologist
Water Quality Engineering Division

APPENDIX F

HEALTH EFFECTS EVALUATION

1. REFERENCES.

a. USEPA-540/1-75-022, DDT, A Review of Scientific and Economic Aspects of the Decision to Ban its Use as a Pesticide, US Environmental Protection Agency (July 1975).

b. Drinking Water and Health, Recommendations of the National Academy of Sciences, 42 FR 35764-35779 (11 July 1977).

2. In discussing the health effects of DDT in man, there are several main concerns. These include the acute toxicity of a single dose of DDT, the toxicity of repeated doses of DDT, and the carcinogenic potential of the compound.

a. The acute single dose manifestations of DDT toxicity are dependent on the dose administered and may include headache, malaise, nausea and vomiting, sensations of numbness and tingling, muscular weakness, tremor, convulsions and coma; very large doses may be fatal.¹ The levels of DDT required to produce acute single dose toxicity are briefly stated in subparagraph 5b(2) of the main report. Toxic effects may be produced in susceptible individuals by dosages as low as 10 mg/kg with convulsions frequently occurring at dosages of 16 mg/kg or greater. The minimum dosage required to produce death in humans is uncertain.²

b. Although the effects of chronic DDT poisoning are well documented in wildlife, little information on such effects is available for man. DDT feeding studies in human test subjects at dosages up to 35 mg/day failed to reveal evidence of illness at the dosages employed.³ Similarly, studies of workers having chronic occupational exposure to DDT failed to reveal evidence of illness.^{2 4}

c. Of primary concern in evaluating the health effects of DDT is the potential ability of this compound to induce cancer in humans. Although studies in other animal species have been inconclusive, DDT has been reliably shown to cause cancer in various strains of laboratory mice. Because mice have been demonstrated to serve as indicators of possible cancer-causing agents, there is concern that DDT may be carcinogenic in man. To date, however, there have been no reported epidemiologic studies showing an association between DDT and human cancer; unfortunately, the epidemiologic studies conducted have been limited by small sample size and short duration.

Because of the positive studies in mice and the absence of adequate human studies, DDT should be considered a possible human carcinogen (reference 1a). The actual risk to humans is uncertain although it can be estimated by a number of means.^{5 6} One such method has been used by the NAS in their recommendations on drinking water standards (reference 1b). Their estimate is discussed in subparagraph 5b(3) of the main report. None of the currently available methods of evaluating the cancer risk to man is entirely satisfactory inasmuch as the theoretical basis for each method is unproven, the mathematical parameters employed are estimates, and the results are largely unvalidated. In any case, all such methods are predicated on the hypothesis that any exposure to a carcinogen results in an increased risk of cancer development which may be estimated. That is, there is no threshold of exposure which must be reached to induce cancer.

3. The levels of DDTR in the potable water at RSA, determined by this special study, ranged from less than 10 ppt to 360 ppt on initial survey. Repeat survey levels of DDTR were less than 10 ppt [paragraph 5b(1), main body of report]. These values represent a negligible health risk to humans. If DDT is a human carcinogen and if the no-threshold hypothesis of carcinogenesis is correct, any increase in exposure to DDT may result in an increase in the population rate of cancer. At the levels measured, however, this rate increase would be extremely small.

4. The levels of DDTR reported from the edible fish and wildlife in the area may represent significant hazards.

a. The levels of DDTR reported in the fish (Tables 1 and 2, Appendix E), although measured in a limited sample, may indicate danger of DDT toxicity in persons eating large quantities of fish. From animal studies, it is believed that mild illness may result from DDT dosage levels as low as 2.5 to 5 mg/kg/day.² These levels may be surpassed in persons subsisting largely on fish from this watershed. It is unlikely, however, that occasional ingestion of fish from the area would be hazardous in terms of acute or chronic DDT intoxication. The levels of DDTR measured in the area's edible birds and mammals (Table 3, Appendix E) are probably low enough that minimal danger of acute or chronic DDT intoxication exists. It should again be noted, however, that the size of the sample examined is small.

b. The major potential risk to persons ingesting the edible fish and wildlife of the RSA area is DDT-induced cancer. The levels of DDT observed to produce tumors in laboratory mice in experimental studies have ranged from 2 ppm to 250 ppm in diet.⁵ In many cases, the levels of DDT measured in the edible game in the Redstone area are greater than those experimental dosages (Tables 1 thru 3, Appendix E). If DDT is a human carcinogen, the risk to people ingesting this game may be considerable, even considering physiologic differences in humans and mice and the fact that the human diet would be

diluted by relatively non-DDT containing foods. Therefore, unless more information becomes available regarding the carcinogenicity of DDT and/or the levels of DDT in the Redstone area edible game, ingestion of these fish and animals must be considered hazardous in terms of carcinogen exposure.

Ronald M. Massey ^{ms}

RONALD M. MASSEY, M.D.
MAJ, MC
Occupational Medicine Officer
Occupational and Environmental
Medicine Division

ANNEX

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APPENDIX G
ANALYTICAL RESULTS

TABLE 1. DRAINAGE SYSTEM SEDIMENT ANALYSES (QUANTITIES EXPRESSED IN PPM)

Sample No.	Location and Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR	Stream Characteristics
1	DDT site drainage ditch as it enters Wheeler Wildlife Refuge	9.00	18.88	10.92	33.14	82.90	473.95	636.99	Continuous flowing drainage ditch with evidence of channel scouring during periods of peak runoff. Little sediment buildup due to stream velocity during storm flows.
2	DDT drainage ditch 20 ft south of SP 1	8.70	21.22	7.26	20.17	54.92	409.80	528.61	Continuous flowing drainage ditch with evidence of channel scouring during periods of peak runoff. Little sediment buildup due to stream velocity during storm flows.
3	DDT drainage ditch 100 ft south of SP 1	ND*	ND*	ND*	6.68	17.73	103.37	128.54	Continuous flowing drainage ditch with evidence of channel scouring during periods of peak runoff. Little sediment buildup due to stream velocity during storm flows.
4	DDT drainage ditch 100 ft north of confluence with Huntsville Spring Branch and approximately 210-250 ft south of SP 3	ND*	5.27	ND*	3.44	8.74	59.77	78.21	Continuous flowing drainage ditch with evidence of channel scouring during periods of peak runoff. Little sediment buildup due to stream velocity during storm flows.
5	Delta area at confluence with Huntsville Spring Branch and DDT drainage ditch	61.99	128.00	63.85	104.00	214.62	1252.11	1865.36	Both streams at this point are very slow flowing. The sample was taken from a sediment delta formed in Huntsville Spring Branch from soils mobilized in the drainage ditch and deposited as the higher velocity of the drainage ditch waters was negated by the slower flowing waters of Huntsville Spring Branch.
6	Huntsville Spring Branch 100 ft southwest of SP 5	56.6	196.8	37.8	74.4	59.1	468.1	934.5	Stream at this point had increased in velocity, however, there was still bottom siltation. This siltation due to lack of plant growth and sandy texture appeared to be of migratory nature and was most probably deposited by previous storm flows.

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Sample No.	Location and Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR	Stream Characteristics
7	Huntsville Spring Branch at the beginning of the reservoir pool approximately 800 ft from SP 6	338.3	365.2	130.7	366.3	383.8	3720.0	5441.2	Stream at this point widens into a reservoir. Velocity decreases and fresh sedimentation of the channel is evident. Surface sediments, probably from last storm, contain coal fragments characteristic of washdown from the DDT plant site.
8	Huntsville Spring Branch-Wheeler Reservoir, North side of reservoir approximately 2000 ft from SP 7	91.52	127.83	27.83	70.65	22.39	542.61	919.06	Reservoir is very shallow at this point. Sediment sample, because of stratification of layers, appears to have been deposited over the duration of several hydrologic events.
9	Wheeler Reservoir near pump house 6407 at the water line of the levee. Approximately 8000 ft diagonally across reservoir from SP 7	4.03	4.55	1.52	4.47	ND*	16.27	32.50	This area is out of the main stream of the reservoir. This area is alternately flooded and exposed as reservoir pool raises and lowers. Sediment is dark and humus laden. No estimate can be made as to age.
10	West bank of Wheeler Reservoir as it passes under Dodd Road	5.64	7.19	2.84	6.26	ND*	3.81	28.24	This area is adjacent to the main channel as it passes under the Dodd Road Bridge. This area is subject to flushing action during high water flows due to channel restrictions created by bridge.
11	West bank of Wheeler Reservoir main channel as it passes under Centerline Road Bridge	9.83	10.47	4.77	11.84	ND*	7.95	49.07	Stream at this point increases slightly in velocity. Sediment is subject to flushing downstream as water level fluctuates and increases or decreases stream velocity.
12	Wheeler Reservoir and Indian Creek approximately 2000 ft southeast of Tow Range	3.34	4.87	2.29	4.06	ND*	1.42	17.64	Sampling point was on east bank of stream and subject to inundation during pool elevation increase. Area was covered with recently deposited sandy loam material.
13	Sandbar in Indian Creek approximately 1000 ft south of SP 12	0.363	0.610	0.132	0.581	ND*	0.049	1.927	Sampling point was on sandbar in Indian Creek. Surface of sand appeared to have been deposited during last high water.

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Sample No.	Location and Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR	Stream Characteristics
14	Sandbar in Indian Creek approximately 1000 ft south of SP 13	8.04	9.63	3.81	10.24	ND*	3.60	38.94	Sampling point was below water line on a sandbar in Indian Creek. Due to velocity differential in this area siltation and erosion were continuous.
15	Indian Creek as it passes target track facility	0.22	0.40	0.53	1.18	0.06	1.12	3.78	Stream was slow moving at this point. Sample taken showed evidence of build-up over long period of time (layers of sand dispersed among leaves and humus material).
16	Indian Creek at its confluence with the Tennessee River near Trianna Boat Dock	1.24	6.99	0.85	5.50	8.31	202.24	226.79	Stream was slow moving at this point. Sample area was from bottom of a small eddy off the mainstream. Sediment appeared to be of recent deposit.

* Limits of detectability are as follows:

Water (ppt) Sediment (ppm)

op'-DDT	10	0.02
pp'-DDT	15	0.03
op'-DDE	10	0.02
pp'-DDE	10	0.02
op'-DDD	10	0.02
pp'-DDD	10	0.02

TABLE 2. BACKGROUND WATER AND SEDIMENT ANALYSES

Sample Point No.	Location and Description	Results
B-1	Sediment sample-Guntersville Lake on the Tennessee River from RS	No detectable DDT isomers
B-1A	Water sample from sample point B-1	No detectable DDT isomers
B-2	Sediment sample-Huntsville Spring Branch at Martin Road	No detectable DDT isomers
B-2A	Water sample from sample point B-2	No detectable DDT isomers
B-3	Sediment sample-McDonald Creek at Bob Wallace Avenue	No detectable DDT isomers
B-3A	Water sample from sample point B-3	No detectable DDT isomers
B-4	Sediment sample-Indian Creek at Highway 20	0.2 ppm pp'-DDE. No other detectable DDT isomers
B-4A	Water sample from sample point B-4	No detectable DDT isomers

Limits of detectability are as follows:

	Water (ppt)	Sediment (ppm)
op'-DDT	10	0.02
pp'-DDT	15	0.03
op'-DDE	10	0.02
pp'-DDE	10	0.02
op'-DDD	10	0.02
pp'-DDD	10	0.02

TABLE 3. SOIL AND GROUND WATER ANALYSES RESULTS DDT MANUFACTURING/DISPOSAL AREA, REDSTONE ARSENAL (QUANTITIES EXPRESSED AS PPM)

Hole No.	Sample	Sample Depth Below Surface	Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR
1	A	7 ft 8 in	Change in soil characteristics at 6 1/2 ft from brown clayey material to light grey material.	<5.33	220.26	75.95	199.73	1,408.08	1,609.20	3,569.76
1	B	9 ft 6 in	Change in soil characteristics just above this level to grey, slightly mottled clay.	6.09	14.99	7.74	15.00	75.99	65.60	190.40
1	C	7 ft	Suspect DDT crystalline material, dark grey color. Apparent perched water table at this depth.	600.01	486.42	356.24	1,291.25	9,263.86	13,469.69	25,779.14
1	D	6 ft 6 in	Dark red silty clay. Sample taken at seam where this material and suspect DDT material meet.	14.08	34.65	26.13	88.61	350.37	337.27	869.75
2	A	Surface	Red silty clay material, possibly mixed with lime.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
2	B	4 ft 8 in	At bottom of red silty clay strata.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
2	C	4 ft 8 in	At top of grey-clayey material strata.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
3	A	4 ft 1 in	At seam where red-clayey material and grey material meet.	<0.04	<0.04	<0.04	<0.04	0.38	2.92	3.30
4	A	2 ft	Red silty clay material.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
4	B	2 ft 6 in	Just above red and grey clay seam.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
4	C	3 ft 8 in	Grey material, nonbinding.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
5	A	1 ft 8 in	Reddish-brown clayey material.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-

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Hole No.	Sample	Sample Depth Below Surface	Description	op'-DDD	pp'-DDD	op'-DDE	pp'-DDE	op'-DDT	pp'-DDT	DDTR
5	B	2 ft 8 in	Grey material just below reddish-brown clay strata.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
5	C	3 ft 6 in	Dark grey clayey material.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
6	A	1 ft	Dark red soil (possibly silt and loam).	<0.04	<0.04	<0.04	<0.04	<0.04	1.04	1.04
6	B	1 ft 10 in	Grey material, non binding.	<0.04	<0.04	<0.04	<0.04	<0.04	1.77	1.77
6	C	4 ft 6 in	Brown and dark grey seam, 1 ft thick at this depth.	<0.04	<0.04	<0.04	<0.04	<0.04	0.66	0.66
7	A	2 ft	Dark red soil (possibly silt and loam).	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
7	B	3 ft 3 in	Light grey with brown clay.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
7	C	5 ft 3 in	Grey with brown clay.	<5.33	<5.33	<5.33	<5.33	<8.00	<8.00	-
8	A	1 ft 6 in	Dark red soil (possibly silt and loam).	<0.04	<0.04	0.48	1.12	3.38	6.00	11.16
8	B	3 ft 3 in	Grey-brown clayey material.	<0.04	<0.04	0.52	1.20	3.43	4.10	9.45
8	C	5 ft	Grey clayey material, oil sheen.	21.18	99.80	102.18	241.47	763.52	838.50	2,119.62
9	A	6 ft 8 in	Ground-water sample from perched water table. Oil sheen.	<0.050	<0.040	<0.050	128	307	560	1,010